COMPARISON OF THE EFFECTS OF TWO THINNING REGIMES ON SOME WOOD PROPERTIES OF RADIATA PINE

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ABSTRACT

Stems from 25-year-old radiata pine trees, grown on the same site, were examined to determine the effects of moderate and heavy thinning on growth rate and several wood properties.

Thinning caused a greater proportion of the volume increment to be accumulated near the base of the stem and effected a temporary decrease in log form. At the time of clear felling, 15 years after the first differential thinning, the heavily thinned stems had a mean tree volume 28% greater than the moderately thinned controls but there was no significant difference in log form. The mean percentage of heartwood was similar in both crops.

Wood density and tracheid length levels were reduced by thinning but there were no significant differences between treatments in tree mean densities at age 25 years. Compared to older unthinned stands of the same mean diameter, the regimes examined here resulted in wood of 8% to 10% lower density and estimated tracheid lengths shorter by 10% or more.

Compression wood formation was found to be related to the rate of growth after thinning and occupied up to 20% of the volume increment of the bottom log for the first 5 years following treatment. This was not associated with increased eccentricity in the stems, but appeared to be a response to the changed environment, possibly through increased auxin production or as a direct result of increased wind sway.

INTRODUCTION

A wood quality study was undertaken on radiata pine (*Pinus radiata* D. Don) from Compartment (Cpt) 1099, Kaingaroa Forest, as part of a broadly based utilisation study. Within this compartment, which had received "normal" silvicultural treatment, was a block of heavily thinned stems. The produce from this block was considered to approximate closely to that expected from short rotation regimes on similar sites (Fenton and Sutton, 1968).

Previous studies have shown that severe thinning and pruning applied to radiata pine crops have only minor effects on the clear wood characteristics of the wood (Sutton and Harris, 1973; Cown, 1973). The above crop offered the opportunity to examine the effects of other silvicultural regimes on 25-year-old trees on a good site.

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MATERIALS AND METHODS

Cpt 1099 is situated in the northern boundary area of Kaingaroa Forest and was planted with radiata pine in 1947. Table 1 summarises the stand history.

TABLE 1—Stand history of Cpt 1099 Kaingaroa Forest

Year	Treatment
1947	Planted at 1.8 × 1.8 m spacing
1948	Blanked
1956/57	Low and high pruned
1957/58	5 ha thinned to 200 stems/ha (plot B) Remainder thinned to 540 stems/ha (plot A)
1966/67	Plot A extraction thinned to 200 stems/ha
1973	Both plots clear felled

Before felling in the summer of 1972/73, diameter and height data from the two treatments were collected, and 80 stems (40 from each plot) covering the range of diameters present were selected for a detailed mensurational study. From these, 10 trees per treatment were chosen for the wood quality study. This subsample also covered the range of diameters, and the mean diameter was close to the mean diameter for the regime.

Discs, 100 mm thick, were removed from internodes at seven positions up the stems, viz, butt (0.3 m), breast height (1.4 m), 6.1 m, and at 6.1 m intervals up to 30.5 m. Apart from the breast height disc, these wood samples represented the ends of adjacent 6.1 m logs up the stem. The inclusion of the 1.4 m disc was intended to lessen the error involved in calculating the volume of the bottom log with data from the butt and 6.1 m discs only.

In the laboratory, one surface of each disc was smoothed using a portable planer. Radial growth was measured along four equidistant radii in such a way as to permit the calculation of heartwood percentage and basal area increments corresponding to each 5-year growth period. Subsequently the discs were sawn in half to yield two smaller disc samples. One such sample was further divided into two diametrically opposed sectors from which wood blocks were sawn for basic density determinations by five-ring groups. The other disc was used for detailed ring width measurements and for the preparation of wood strips to be used in the beta-ray densitometer (Harris, 1969). This latter disc was also used for broadly estimating the amount of compression wood in each ring.

Tracheid lengths were measured in macerated tissue from the rings 1956-57 and 1960/61, i.e., immediately before and 3 years after thinning. A more detailed study was not considered necessary as previous work has shown mean tracheid length to be inversely related to ring width (Cown, 1972; 1973), and the above sample was expected merely to confirm this.

RESULTS

Fig. 1 summarises the growth and density data for the mean tree within each treatment. The outlines of the underbark dimensions represent the wood profiles on completion of each 5-year growth period from 1947 to 1972.

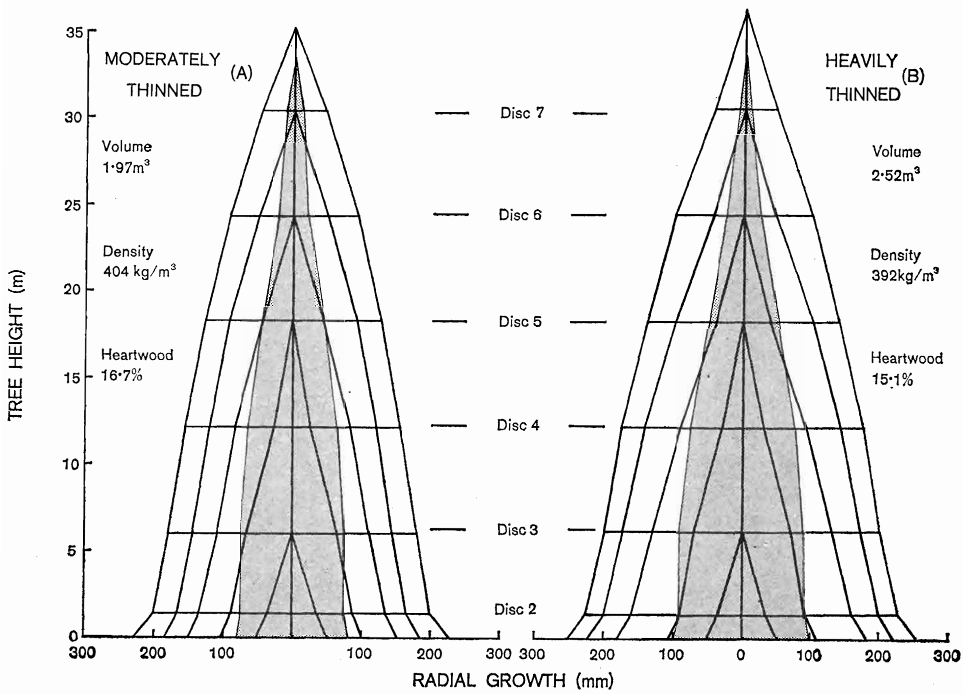

FIG. 1—Growth and density data for the mean tree within each treatment. The shaded area indicates heartwood

The mean tree volumes of the moderately thinned and the heavily thinned samples were 1.97 m^3 and 2.52 m^3 respectively, i.e., a difference of 28%. There were no statistically significant differences in either mean heartwood percentage or mean wood density. This does not mean that the treatments influenced only the volume increment of the stems, as the following sections will show.

Radial Growth and Volume Increment

Fig. 2 shows the radial trends in ring width and basal area increment (b.a.i.) at the various positions up the stems.

There was a very pronounced response to thinning in both plots in 1957/58 and plot B maintained a higher growth rate until plot A received its second thinning in 1966/67.

The effects of the regimes on the distribution of growth within stems are shown in

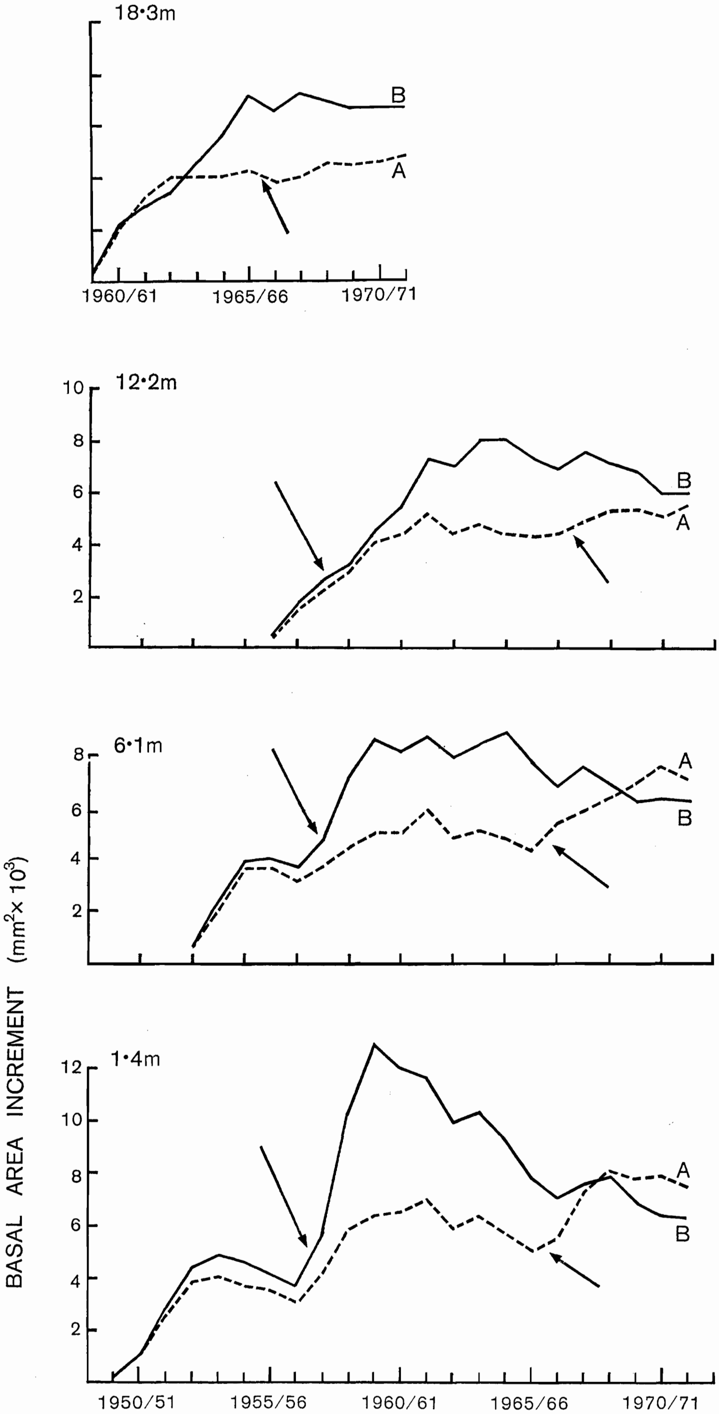

FIG. 2—Basal area increments in Plots A and B

Fig. 3. In the first period after thinning, i.e., 1958 to 1962, the differential growth between plots ranged from 75% in the butt log to 11% in log 3, and −23% in the top log, suggesting an appreciable change in form. During the period 1963 to 1967

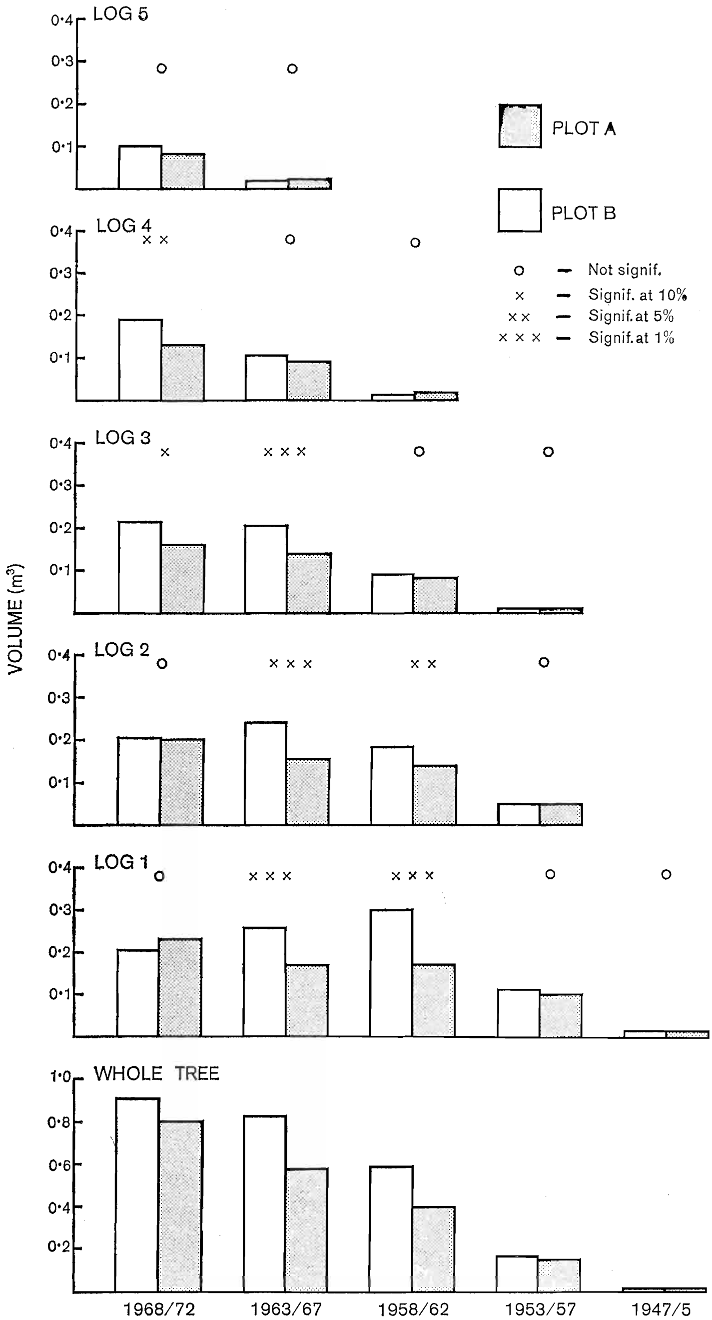

FIG. 3—Distribution of volume by logs and 5-year increment

a redistribution of volume occurred and the differential in the bottom three logs was uniformly about 50%.

A similar trend was apparent following the second thinning of plot A in that over the period 1968 to 1972 volume increment in the butt log was 10% greater than in plot B. Second log increments were similar between plots but higher up the stem the B regime maintained its faster growth.

The ring width data were used to calculate underbark form factors in the first and second logs. The formulae used were as follows:

Form Factor of Log 1 = DIAM. 6.1 m/d.b.h.
Form Factor of Log 2 = DIAM. 12.2 m/DIAM. 6.1 m
Form Factor of combined logs = DIAM. 12.2 m/d.b.h.

Fig. 4 shows how these altered during the rotation.

Despite the pronounced redistribution of volume after thinning, there were only small changes in the shapes of the logs and even these differences were corrected after about 5 years. The second thinning in plot A had a negligible effect on log form.

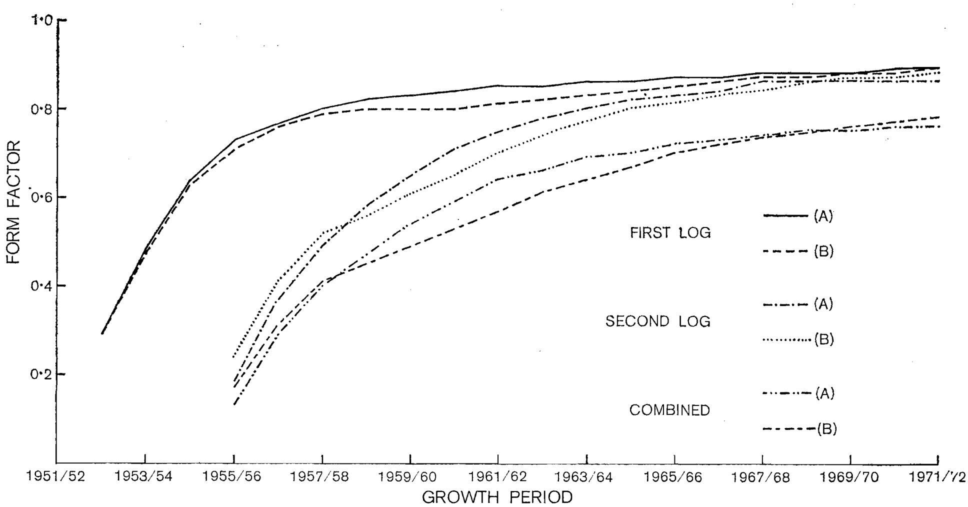

FIG. 4—Log form factor

Heartwood

The smoothed surfaces of the freshly cut discs showed very clearly the boundary between the sapwood and the dry wood zone. The true heartwood boundary normally lies about 10 mm within this and is often very difficult to distinguish. For this study, therefore, "heartwood" was taken as the true heartwood plus the dry wood zone, which gives an over-estimate.

The values obtained showed a large tree-to-tree variation ranging from 7.9% to 20.0% in plot A and 7.3% to 23.5% in plot B. There was no difference between treatments in this respect.

Compression Wood

Each growth ring in the sample discs was examined for the presence of compression wood and ascribed a number from one to four depending on whether the average incidence covered up to $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, or the whole ring. The plot mean value for each year was halved to give a rough estimate of the actual incidence in each growing season. No allowance was made for the degree of compression wood found (i.e., mild or severe). The results are presented in Fig. 5.

Pronounced trends were apparent near the bases of the trees, very strong positive correlations were found between growth rate and incidence of compression wood following thinning in the butt and breast-height discs of both plots A and B (r^2 = 74% and 89% respectively). These relationships are surprisingly good considering the somewhat superficial way in which the compression wood was measured.

These correlations were determined within the sapwood only, as it was found that the presence of heartwood made the identification of compression wood much more difficult. In any case, the distinct patterns of ring width which occur in the core wood of radiata pine would adversely affect the relationships.

The r^2 values rapidly diminished with increasing height in the stem, particularly in the plot A trees. This appeared to be due to a combination of the decreasing influence of thinning on growth rate and the increasing proximity of the treated portion of the stem to the pith.

Wood Density

The basic density values for the five-ring wood blocks are shown in Table 2, with apparent differences between the two plots in certain parts of the stem and in certain growth periods. Whereas the greatest differential in volume increment occurred from 1958 to 1962, the greatest density differential was from 1963 to 1967. In both cases there were distinct trends vertically within the stems and, as with volume, the density responses were mainly at the base of the tree. Statistically significant differences were found in the butt, breast height, and 6.1 m discs only (figures for the butt discs are not given in Table 2) and in the 1963 to 1967 period only. However, the trends suggest that the heavy thinning had, in relation to the other plot, reduced density in the outer 10 rings up to disc 5.

Plot A trees showed a 23% increase in density at breast height, from an average of 366 kg/m^3 for the inner 10 rings to 452 kg/m^3 in the outer five rings. The corresponding figure in the heavily thinned stems was 16%, from 380 kg/m^3 to 441 kg/m^3. Student's t test on these trends indicated that the difference was significant at the 10% level only. The weighted tree mean values gave an average of 404 kg/m^3 for the plot A samples and 392 kg/m^3 for the plot B samples, a non-significant difference.

Density trends were analysed on radial densitometer samples from the breast height, 6.1 m, and 12.2 m discs. Fig. 6 shows how the two plots compared.

The trend of increasing densities outwards from the pith was abruptly halted following thinning, particularly in the B treatment at the 6.1 m level. All three density parameters measured responded in this way. Density levels in the plot A stems also decreased after the second thinning.

These results corroborate the findings from the block density part of the study and demonstrate that thinning has had a measurable influence on wood density. The maximum difference recorded in any one year was 16% in mean density at the 6.1 m level

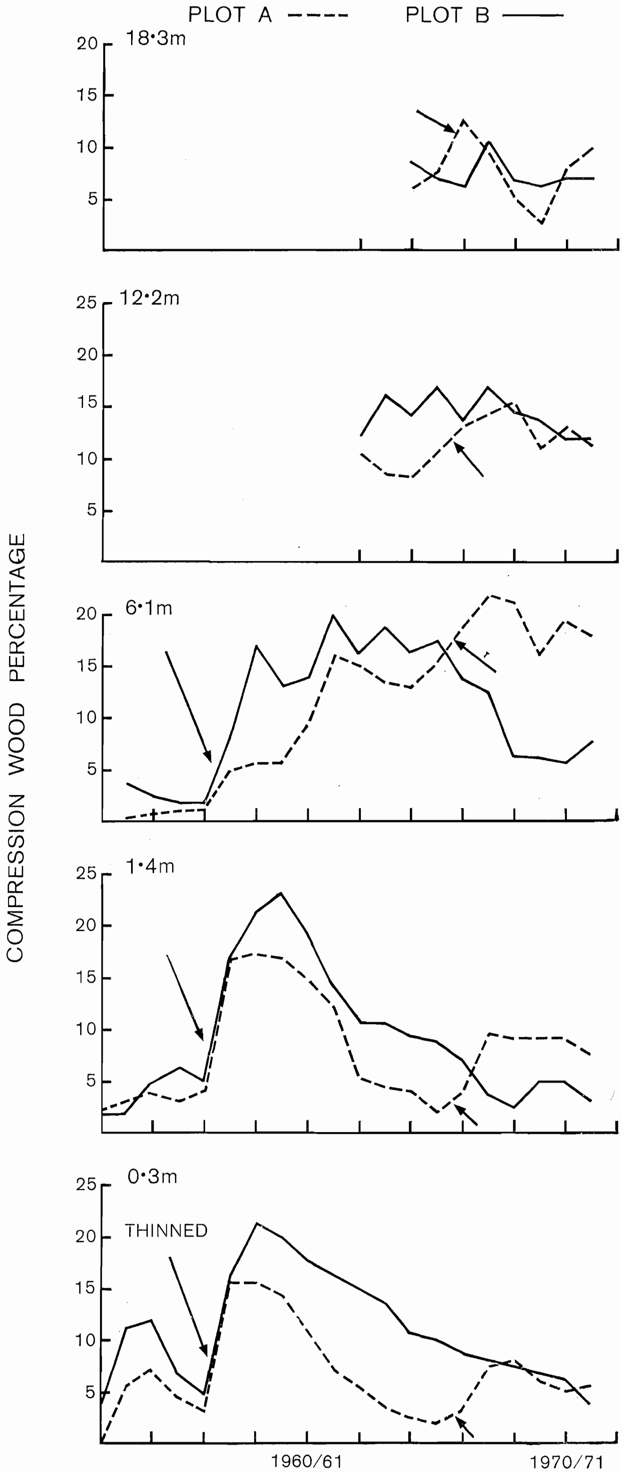

FIG. 5—Incidence of compression wood

TABLE 2—Distribution of basic density (kg/m³) by discs and 5-year increments

Disc no.	Ht. (m)	Plot	Five-year growth period 48/52	53/57	58/62	63/67	68/72	Weighted mean
2	BH	A	358	374	420	454)	452	427
		B	378	383	415	412)	441	414
3	6.1	A		336	386	443))	447	414
		B		338	382	401))	432	394
4	12.2	A		344	351	411	431	399
		B		338	353	379	417	382
5	18.3	A			345	374	404	384
		B			345	367	392	377
6	24.4	A				350	375	368
		B				350	377	372
7	30.5	A					350	350
		B					356	356

Difference significant at:) 5%,)) 1%.

during 1966/67. The mean difference for the period from 1963 to 1967 was 12% at the same height, compared with 10.5% in the wood blocks.

It is interesting that the greatest differences in density occur in the second 5-year period after treatment and at the 6.1 m level, whereas the largest differences in radial growth occurred within 5 years of the treatments and at the butt and breast-height levels.

Tracheid Length

Previous studies with radiata pine in New Zealand have indicated that tracheid length and radial growth are inversely related (Cown, 1972; 1973). Current results are summarised in Table 3.

At the breast-height level, mean tracheid length dropped between 1956/57 and 1960/61. Since tracheid length normally increases outwards from the pith, the thinning

TABLE 3—Summary of tracheid length data

Height (m)	Growth Period	Tracheid Length (mm) Plot A	Plot B	Student's t	Significance
1.4	1956/57	3.39	3.33	0.69	n.s.
	1960/61	3.31	2.99	3.06	***
6.1	1956/57	3.29	3.23	0.80	n.s.
	1960/61	3.46	3.31	1.37	n.s.
12.2	1956/57	2.00	2.37	3.13	***
	1960/61	3.13	3.06	0.66	n.s.

n.s. = not significant
*** = significant at the 1% level

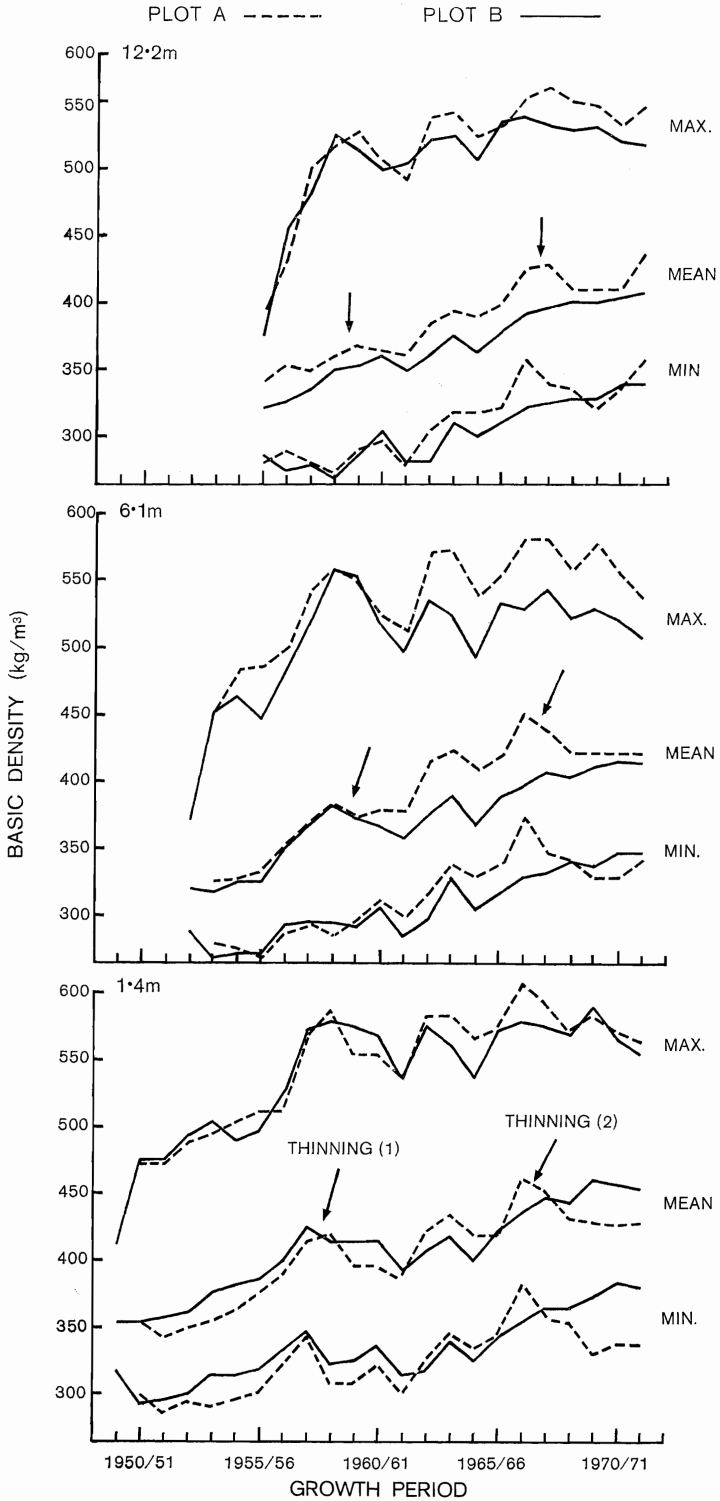

FIG. 6—Densitometer records for Plots A and B

has had the effect of reducing the mean values. Heavy thinning has resulted in a reduction significantly greater than in the moderate thinning. Further up the stems the differences between plots for 1960/61 were non-significant. The highly significant result for 1956/57 at the 12.2 m level is something of an anomaly in that this growth period coincided with the second ring outwards from the pith in most cases. Three plot A trees, however, had one ring less than the others at this height which meant that some samples were taken from the ring adjacent to the pith, thus giving a lower mean value and an apparently significant difference between plots. The effect of thinning on tracheid length is significant only in the lower portion of the stem.

DISCUSSION AND CONCLUSIONS

This study has shown that thinning in a semi-mature crop of radiata pine can affect volume increment and distribution within stems, and wood properties.

The extent to which radial growth is altered depends on the severity of thinning; the greater the reduction in stocking, the greater the differential between growth at the base and growth at the top. This change of form corrects itself after several years. It would suggest that crops harvested at full stocking will produce logs of similar form irrespective of silivicultural treatment.

The heartwood data showed that there were no significant differences between plots at the end of the rotation. Thinning, however, may have a small effect at the time, e.g., by increasing the proportion of sapwood for a period after treatment. The current data confirm that large differences in heartwood content occur between trees in a crop.

A very interesting result is that formation of compression wood was found to be related to growth rate, particularly in the lower discs sampled. Reaction wood has often been shown to be accompanied by differential radial growth (Wardrop, 1965) and it was at first thought that this may have contributed to the observed results. However, a re-examination of the basic data revealed that thinning had not appreciably affected the eccentricity of the stem.

The most likely explanation is that thinning has altered the hormonal balance within the stems, either directly or indirectly. High concentrations of auxins promote both radial growth and compression wood formation (Brown, 1971). The redistribution of volume increment for several years following thinning is evidence that the trees have responded in such a way as to more closely approximate the open-grown pattern of growth, and the short-term effect of this would be to permit the retention of a deeper and wider crown. This would in turn tend to induce high levels of auxin (Larson, 1962) which could be directly involved in the formation of compression wood. A different hypothesis is that thinning may have made the stems more prone to windsway and that compression wood has formed as a response to the external environment.

Whatever the reason, thinning resulted in the formation of compression wood and the frequency of incidence was related to the magnitude of the growth response. The method of measurement, although fairly crude, indicated that heavy thinning could lead to compression wood comprising up to 20% of the volume increment of the bottom log for several years.

The normal trends of increasing wood density outwards from the pith in unthinned radiata pine (Harris and Nash, 1972) were clearly affected by the thinning treatments. In both moderately and heavily thinned plots, density levels tended to level off or even decrease slightly for several years after treatment. As in other studies (Cown, 1973) the effect of silvicultural treatment was less apparent up the stem.

In comparison with unthinned stands in the same area (Harris and Nash, 1972), the heavily thinned plot was producing wood of average density 5% less at breast height for the 10 years after treatment. To gauge the significance of this result, the combined effects of growth rate and density must be examined. Unthinned crops in northern Kaingaroa have cross-sectional breast height densities of around 450 kg/m^3 at 400 mm diameter (unpublished data) compared to 420 kg/m^3 at the same diameter in plot B, i.e., a difference of 7%. The difference in the age required to attain this diameter under the two regimes is about 10 years.

Since radial density trends are essentially the same at all levels in the stem, trees grown on a shorter rotation will have lower cross-sectional densities throughout their boles. With increasing height in the stem, the difference between two such regimes at the end of the rotation will tend to be greater since the density increase is more pronounced close to the pith. In the example given above, the unthinned trees would have an additional 10 growth rings at all stem levels. On this basis, the short rotation regimes proposed by Fenton and Sutton (1968) can be expected to yield wood of mean density about 8% to 10% lower than that of wood from unthinned stands on similar sites. This is mainly due to the reduction in time taken to reach merchantable size rather than to any effect of the thinning on density trends.

Similar arguments can be applied to tracheid length except that growth rate has a much stronger influence than it has with density. In this case short-rotation produce would probably have mean lengths 10% or more less than those in unthinned stems.

These results were more or less expected on the basis of previous work, but the fact that compression wood may be associated with fast growth rates has not hitherto been seriously considered.

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